

Final Report to
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

Grant NAG 2-143
(University No. 345690)

For Support of
Continuing Participation in the
Pioneer Venus Mission

Submitted by

Donald M. Hunten
Regents Professor
The University of Arizona
Lunar and Planetary Laboratory
and
Department of Planetary Sciences
Tucson, Arizona 85721
(520) 621-4002

May 17, 1996

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Scientific Objectives

This document reports the activities of D.M. Hunten as Interdisciplinary Scientist, Co-Investigator on the ONMS, vice-chairman of the SSG, chairman of OMOP, and advisor to the Project. With the full-time collaboration of Dr. S.W. Bougher, the scientific program focused on the circulation, composition, and structure of the Venus thermosphere. (Part of Dr. Bougher's support came through a Guest Investigator grant). The major tool is a Thermospheric General Circulation Model at the National Center for Atmospheric Research. Data bases used for comparison and control came mainly from the ONMS and the OUVS. We continued (with greatly improved techniques) the Earth-based search for lightning flashes started in April 1988; a key figure in this effort was Dr. K. Wells. Wells and graduate student Seth Hansell actually detected seven flashes in March 1993, and Hansell is continuing the program in 1996. We participated in the events during final entry and two ONMS papers.

Key Personnel

D.M. Hunten, Regents Professor, was Interdisciplinary Scientist on PV, and carried out additional duties summarized above.

S.W. Bougher, Senior Research Associate, was partly supported by the present grant and partly from his PV Guest Investigator grant and a NASA grant.

W.K. Wells, Senior Research Associate, was responsible for the equipment used in the lightning detection, and participated in the observing and analysis.

Scientific and Project Activities:

Hunten completed his Project-related activities as advisor, vice-chairman of the SSG, and chairman of OMOP.

1. Thermospheric Circulation, Structure, and Composition -- This work was carried out by Bougher, with occasional consultation with Hunten. Although it was mostly supported by Bougher's PVGI and NASA grants, it is reported here for coherence. Keating and Bougher (1992) identified beyond reasonable doubt the principal cooling mechanism of the thermosphere, excitation of the bending mode of CO₂ by collision with atomic oxygen. Others have recently and independently shown the importance of this same mechanism for the Earth. It also explains the curious fact that the Venus exospheric temperature responds more strongly to short-term solar variability than to changes on the time scale of the sunspot cycle. On the long scale, higher solar activity increases the O density and therefore the cooling rate, thus offsetting the greater solar heating. The subject was reviewed by Bougher, Hunten and Roble (1994).

2. Telescopic Search for Lightning -- Data were obtained at the 1991 apparition, with a coronagraph attachment on the 61-inch telescope and a CCD camera. Observations were made by Wells and a student, S. Hansell, and analyzed mainly by Hansell. There was no evidence of flashes. For the 1993 apparition the coronagraph was greatly improved and a rapid-framing CCD camera was available. Good evidence was found for 7 flashes (Hansell et al., 1995). With the departure of Wells, Hansell took up the project and made still further improvements, so that lightning and background channels can be observed simultaneously. As these words are written, Venus is again approaching inferior conjunction, and Hansell is in the middle of a series of runs which so far look extremely promising.

3. Final Entry -- Huntен and Bougher were involved with the two ONMS papers involving data from the entry phase in mid-1992 (Kasprzak et al., 1993a, b). Temperatures were not much different from those during the primary phase of the mission, even though solar activity was very different. The position of the helium bulge was also unchanged, implying that the super-rotation velocity of the thermosphere was about the same. The second paper describes the observation of wavelike phenomena.

Scientific Meeting:

COSPAR, Washington, Aug. 28 - 30, 1992: Huntен presented a paper "Venus lightning: Pros and Cons" at the Venus symposium, now printed in "Advances in Space Research" (Huntен, 1995).

SSG meetings and related activities (all at ARC):

July 30 - 31, 1992: Huntен chaired an OMOP meeting and participated in the Entry Planning Committee meeting.

September 8-10, 1992: Huntен and Bougher attended the SWG and SSG meetings. Huntен also chaired the OMOP/EPC.

March 21 - 23, 1993: Huntен attended the SSG meeting.

Sept. 13 - 14, 1993: Huntен attended the final SWG meeting and the farewell dinner.

Publications

Bougher, S.W., Huntен, D.M. and Roble, R.G. (1994). CO₂ cooling in terrestrial planet thermospheres. J. Geophys. Res. 99, 14,609 - 14,622.

Hansell, S.H., Wells, W.K. and Huntен, D.M. 1995. Optical detection of lightning on Venus. Icarus 117, 345 - 351.

Huntен, D.M. 1995. Venus lightning: Pros and Cons. Adv. Space Res. 15(4), 109 - 112.

Kasprzak, W.T., Niemann, H.B., Hedin, A.E., Bougher, S.W. and Huntен, D.M. 1993a. Neutral composition measurements by the Pioneer Venus Neutral Mass Spectrometer during Orbiter re-entry. Geophys. Res. Lett. 20, 2747 - 2750.

Kasprzak, W.T., Niemann, H.B., Hedin, A.E. and Bougher, S.W. 1993b. Wave-like perturbations observed at low altitudes by the Pioneer Venus Orbiter Neutral Mass Spectrometer during Orbiter entry. Geophys. Res. Lett. 20, 2755 - 2758.

Keating, G.M. and Bougher, S.W. 1992. Isolation of major Venus thermospheric cooling mechanisms and implications for Earth and Mars. J. Geophys. Res. 97, 4189 - 4207.